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No. 430

EFFECTS OF ROUGHNESS ON AIRFOILS

By O. Schrenk

From Report III
"Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen"

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EFFECTS OF ROUGHNESS ON AIRFOILS.*

By O. Schrenk.

As a continuation of the experiments on airfoils with roughened pressure (i.e., under) sides (see Report I, No. IV, 4 of "Ergebnisse der Aerodynamischen Versuchsanstalt zu Gottingen"), we will here report on the effects of coarsely roughening not only the pressure side but also the suction or upper side of airfoils, as the first group of a larger series of experiments.

The airfoil used for the roughness experiments was a hollow sheet-metal airfoil of 120 cm (47.24 in.) span and 30 cm (11.81 in.) chord. It had a rectangular plan and the same profile or cross section throughout (profile 449 from the series in Report I, pp. 101 and 112). For the roughening, a wire gauze of 0.5 mm (.02 in.) wire with square meshes (38 in 10 cm or 9.65 in 1 in.). The wire gauze was soldered to the airfoil with one set of wires parallel to and the other set perpendicular to the edges of the airfoil. The location and width of the roughened portions of the airfoil are shown in Figs. 1 and 2. For comparison, the airfoil was also tested with a perfectly smooth surface. The fol-

*"Rauhigkeitseinflüsse an Tragflügeln," from "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen," Report III, pp. 113-114. (See also N.A.C.A. Technical Memorandum No. 375.)

lowing cases were tested:

I. Pressure side rough (Fig. 1);

II. Suction side rough (Fig. 1);

III. Both sides rough (I and II) (Fig. 1);

IV. Roughness near leading edge (Fig. 2);

V. Roughness in middle of airfoil (Fig. 2);

VI. Roughness at trailing edge (Fig. 2).

(Cases IV-VI were only on the suction side.)

The results are shown graphically in Figs. 3-4, and numerically in Tables I-VII. At the same angle of attack, as here shown, roughness on the pressure side generates a somewhat greater lift. This is accompanied, however, by a considerable increase in the profile (or wing-section) drag, thus reducing the lift-drag ratio. The maximum lift is somewhat less than that of the entirely smooth wing. Moreover, these results confirm the results of previous tests on an airfoil with rough pressure side (p. 69 of the First Göttingen Report).

Roughening the suction side produces a considerably more unfavorable result. This not only increases the drag, but also decreases the lift considerably. A similar result is also shown by the polar curve for the airfoil roughened on both sides. Even these first experiments demonstrate the importance of a smooth upper surface. Roughness on the under side is not so bad, though even here it is advantageous to have the surface as smooth as possible.

The relative sensitiveness to roughness of the different portions of the surface is shown by cases IV-VI, in which only single portions of the suction side were roughened, as shown in Fig. 2. Practically no effect was produced by roughening the trailing edge (case VI), the polar curve almost coinciding with the one for the smooth airfoil. A greater effect was produced by roughening the central portion (case V) and a still much greater effect was produced by roughening the portion near the leading edge (case IV), which is especially sensitive to all disturbances. Here there was a very noticeable increase in the drag and a considerable decrease in the lift. Moreover, the flow here becomes detached at relatively small angles of attack.

TABLE I.

Case I. Pressure side rough.

α	100 c_a	100 c_w	100 c_m
-11.0°	-11.0	7.34	4.4
- 9.0	+ 1.2	4.41	10.3
- 6.1	18.1	3.34	14.8
- 3.2	35.5	3.53	18.9
- 0.3	51.3	4.46	22.5
+ 2.6	67.2	6.00	26.1
5.5	82.4	8.05	29.2
8.4	96.5	10.4	32.2
11.3	106.2	13.3	34.2
14.3	111.5	16.9	34.9
17.3	109.2	20.8	35.0
19.3	108.0	23.5	34.8

TABLE II.

Case II. Suction side rough.

α	100 c_a	100 c_w	100 c_m
- 8.8°	-25.1	3.94	-0.7
- 5.9	-11.2	3.74	+2.2
- 3.0	+ 0.2	4.06	4.1
- 0.1	16.5	5.10	8.5
+ 2.8	29.2	6.77	12.0
5.7	41.0	9.18	15.5
8.7	50.3	12.2	18.6
11.6	57.0	15.7	21.2
14.6	63.4	19.8	23.8
17.6	74.1	25.3	28.5
20.5	82.2	31.8	33.1

TABLE III.

Case III. Both sides rough.

α	100 c_a	100 c_w	100 c_m
- 9.1°	+19.2	13.9	-3.19
- 6.1	-10.1	6.05	+2.01
- 3.0	+ 2.1	5.67	4.60
- 0.1	15.2	6.41	7.78
+ 2.8	28.1	7.95	11.1
5.7	39.3	10.4	14.3
8.7	46.2	13.1	16.7
11.7	52.6	17.0	19.2
14.6	56.3	21.1	21.2
16.1	61.8	23.4	25.5
17.6	66.3	26.9	26.2

TABLE IV.

Case IV. Roughness near leading edge.

α	100 c_a	100 c_w	100 c_m
-11.9°	-15.5	6.80	4.4
- 8.9	-10.8	2.13	5.6
- 6.0	+ 4.4	2.02	8.2
- 3.1	19.5	2.42	11.0
- 0.2	33.6	3.28	13.6
+ 2.7	45.8	4.67	15.9
5.6	56.4	7.10	18.5
8.6	62.6	10.7	21.0
11.6	63.3	15.1	23.2
14.6	65.3	20.5	24.6
16.0	70.0	22.9	26.8
17.5	78.3	26.6	31.6
19.0	81.8	29.3	32.4

TABLE V.

Case V. Roughness in middle.

α	100 c_a	100 c_w	100 c_m
-11.9°	-19.1	6.84	2.2
- 8.9	-10.1	2.27	5.5
- 6.0	+ 6.8	2.04	8.9
- 3.2	23.7	2.40	12.9
- 0.3	40.5	3.35	16.7
+ 2.6	55.7	4.89	20.4
5.6	67.2	7.33	23.4
8.5	78.8	10.0	26.4
9.9	84.6	11.4	27.9
11.4	90.5	13.2	29.8
12.9	92.5	13.5	30.1
14.3	101.9	16.2	32.7
17.3	111.3	20.6	36.6
18.8	112.8	22.5	37.4
20.3	111.8	25.1	37.8
21.7	114.1	27.9	39.4
23.3	113.5	31.2	40.1

TABLE VI.

Case VI. Roughness at trailing edge.

α	100 c_a	100 c_w	100 c_m
-11.9°	-19.9	6.45	2.2
- 8.9	- 9.8	1.75	6.9
- 6.1	+10.4	1.57	10.9
- 3.2	27.6	1.99	14.7
- 0.3	45.4	3.01	19.0
+ 2.6	62.2	4.47	23.0
5.5	79.7	6.73	27.6
8.4	96.5	9.55	31.8
11.3	108.6	12.7	35.0
14.2	116.4	16.2	36.9
17.2	115.5	20.8	37.7
18.7	115.0	22.6	37.4
20.2	114.5	24.9	38.0
23.3	113.0	29.8	39.1

TABLE VII.

Case VII. Smooth airfoil.

α	100 c_a	100 c_w	100 c_m
- 9.0°	- 6.7	1.64	8.6
- 6.1	+10.2	1.47	12.4
- 3.2	27.9	1.87	16.2
+ 0.3	44.6	2.90	20.0
2.6	60.5	4.30	23.4
5.5	79.7	6.67	28.5
8.4	93.8	9.14	31.8
11.3	107.9	12.4	34.6
14.2	115.1	15.5	36.4
15.5	116.7	17.6	36.9
17.2	115.0	19.9	36.8
19.3	113.3	22.8	37.1

Translation by Dwight M. Miner,
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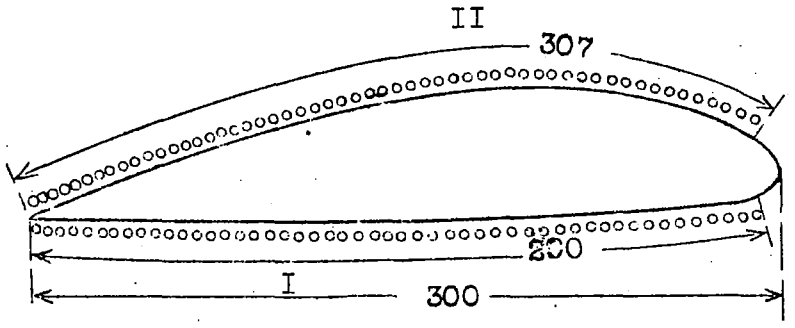


Fig.1

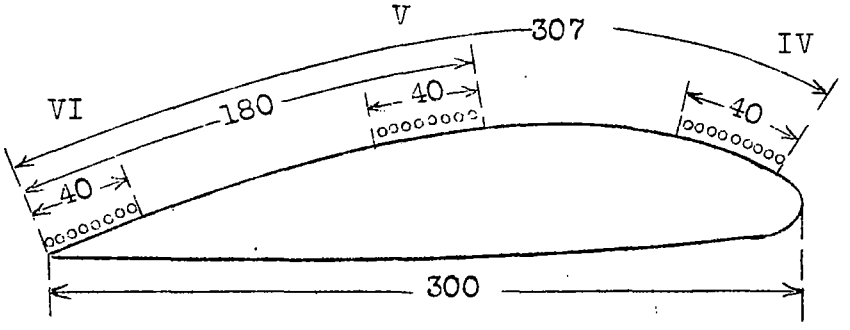
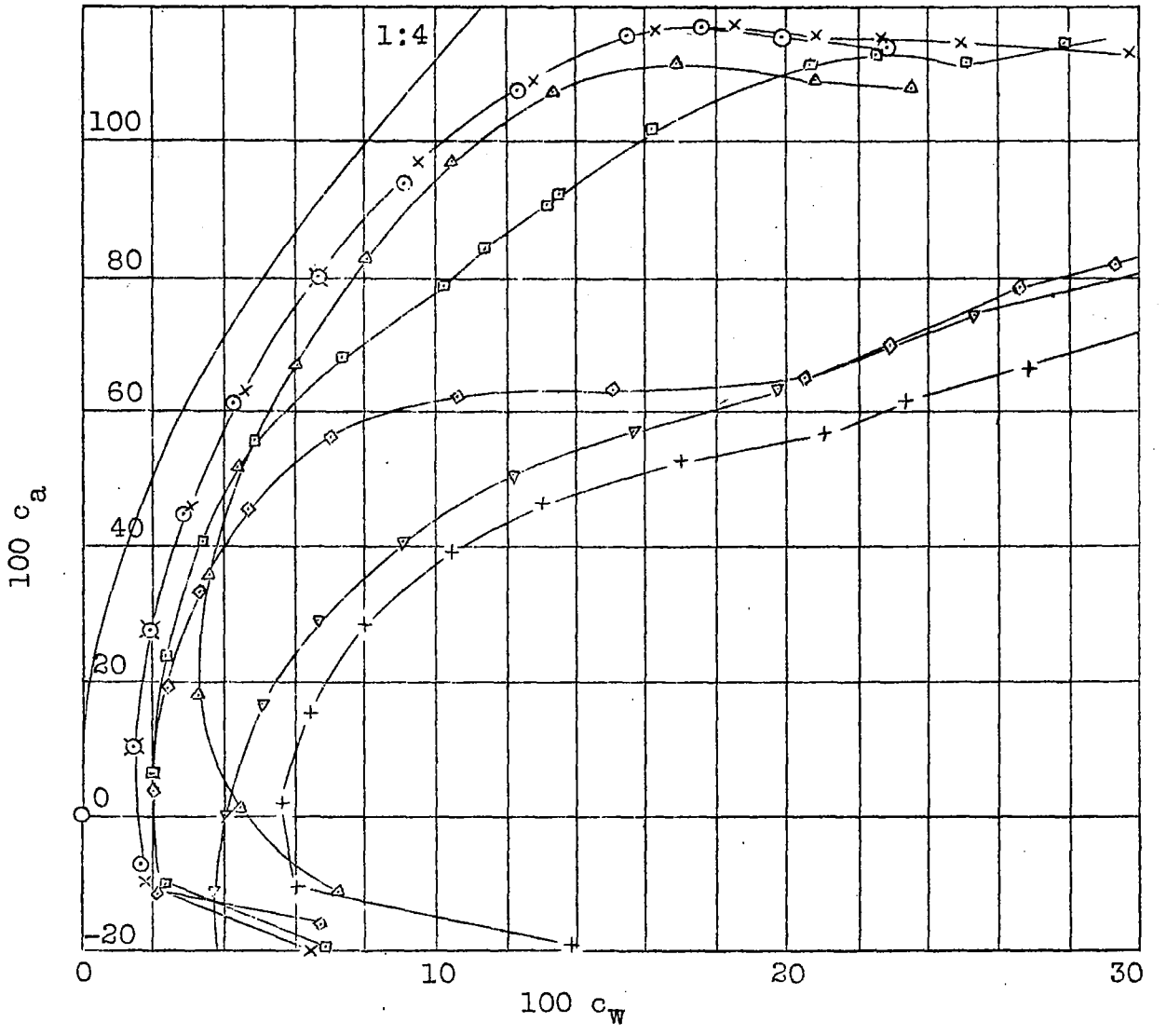
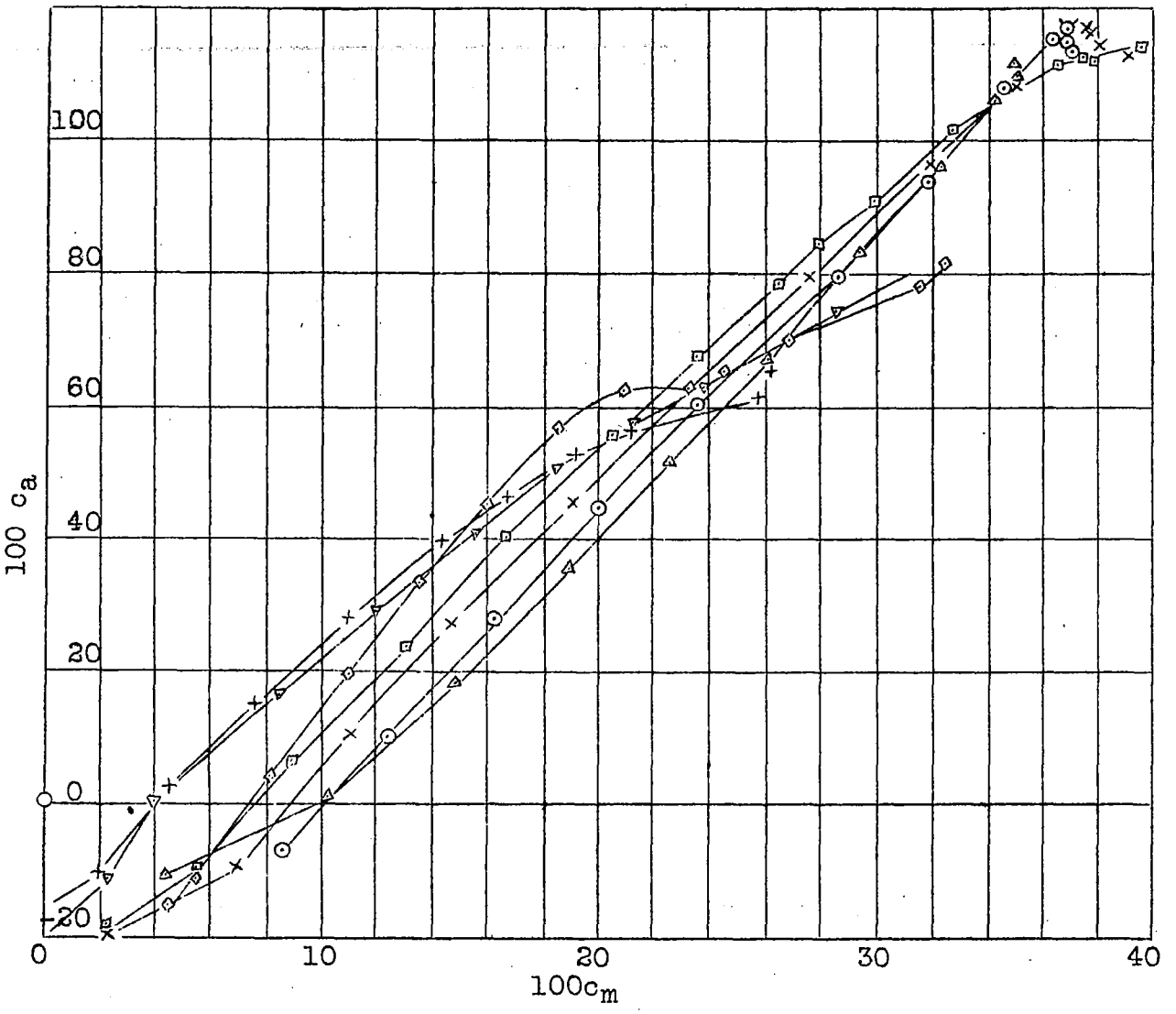


Fig.2



△ Roughness I
▽ " II
\+ " III
◇ " IV
□ " V
× " VI
⊙ Perfectly smooth

Fig.3



△ Roughness I
▽ " II
\+ " III
◇ " IV
□ " V
× " VI
⊙ Perfectly smooth

Fig.4